



ARISE Flight Planning

7/14/14, Rev E

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ARISE Flight Planning Matrix

a real-time tool to help capture and implement broad mission objectives



C-130 Range Circles

Range Circles Map - Fairbanks

Assumptions for this Map

1. 300knots is the average speed LVIS used/saw last year in the C130 when transiting/flying at ~27,000'.
2. 180knots is the speed that Jeff gave for flying in clouds and at lower altitudes (slowest speed possible?).
3. These circles assume 8 hour missions based from Fairbanks.

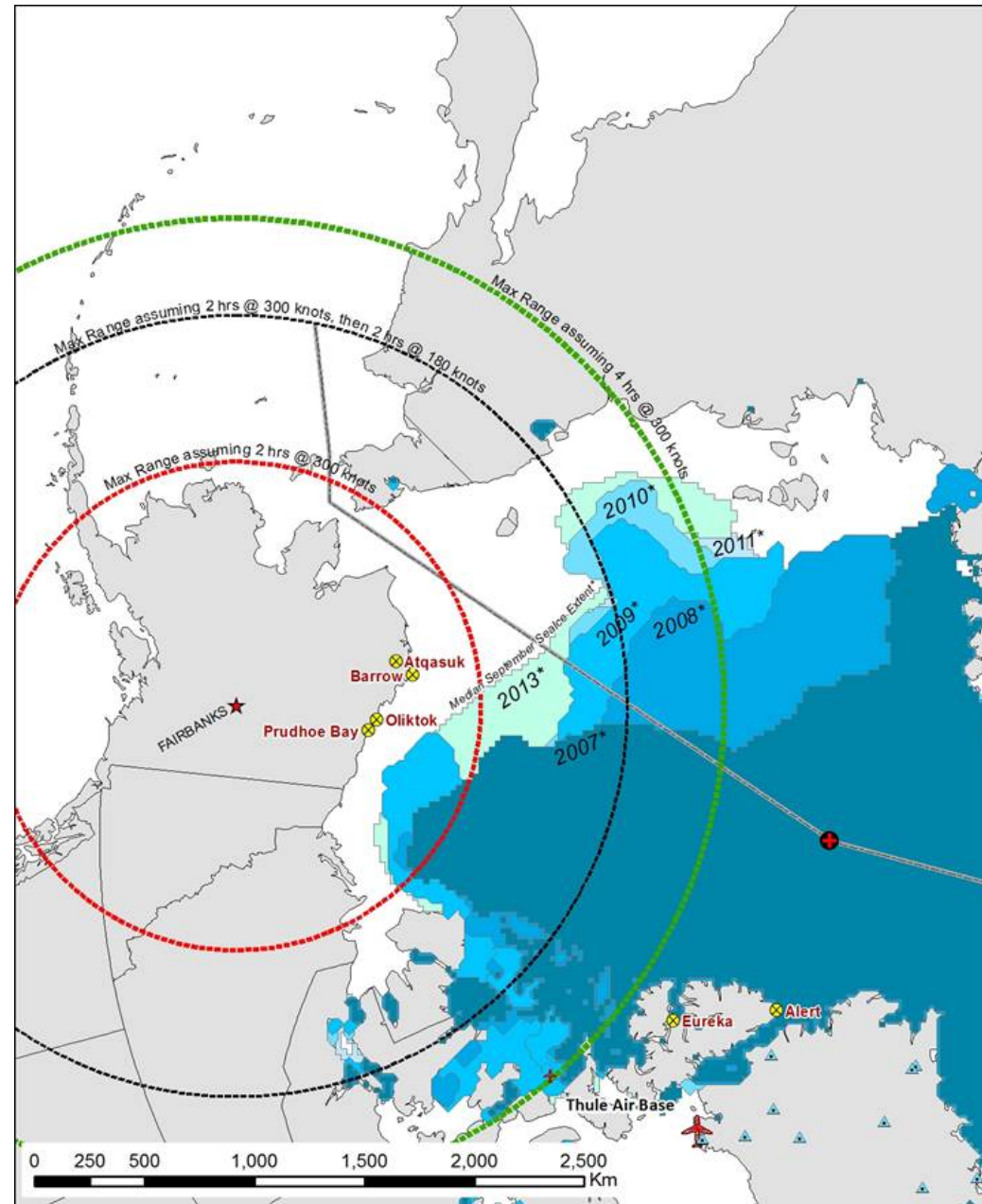
Dashed Circles Key:

Red: how far the plane could reach in 2 hours at higher altitude (300knots and 27,000'ish). So if we went to the red line and back, that's a 4 hour flight. That circle shows that the ice edge is reachable in ~2hours (some years, less time needed, some years, more time needed..).

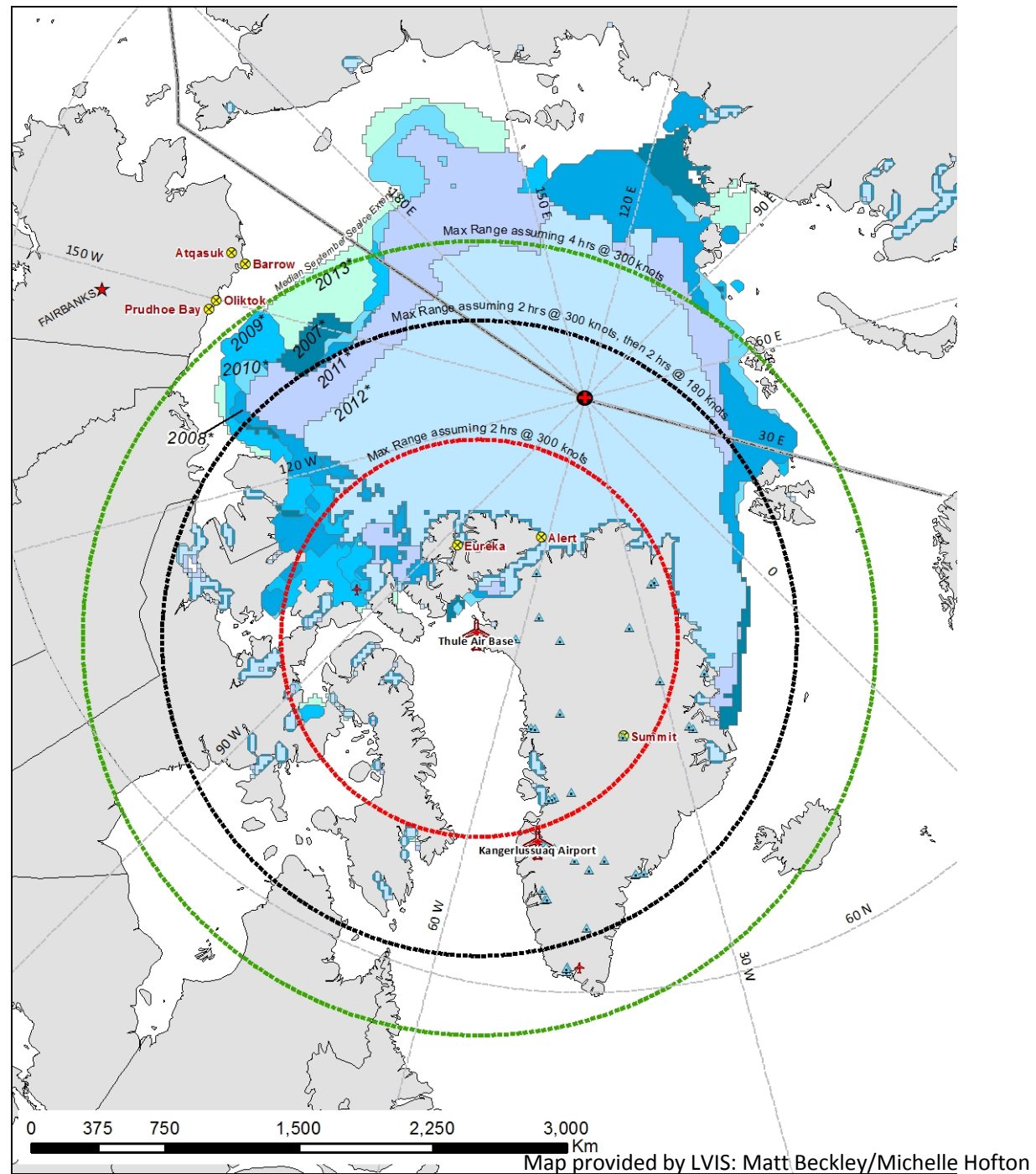
Green: how far the plane can get in 4 hours at 300knots/higher altitude. So if we went to the green line and back and saw an average of 300knots, that would be an 8 hour flight

Black: This one is how far the plane could reach if we flew to the red circle at higher altitude/300knots, then dropped in altitude and flew at 180knots for 4 hours. So its 2 hours to reach the red circle (@300knots), then 2 hours to reach the black circle (@180knots), turn and repeat back to Fairbanks. For a total of 8 hours.

Note: Another way to look at it: we can do whatever we want outside of the red circle, as long as 6 hours after take off we are at or within the red circle



Range Circles Map - Thule





Radiation Flight Line Planning

Assumptions

1. All instruments will record data at all times, regardless of primary flight objective
2. Even though this presentation shows separate lines for radiation vs. ice targets, objectives can and will overlap; where feasible, we will try to obtain multiple objectives in any given flight



Proposed flight plans for CERES validation

*Seiji Kato, Norman Loeb,
Joseph Corbett, Patrick Taylor
and the CERES team*

What is the CERES Instrument?

CERES: Clouds & Earth's Radiant Energy System

The CERES experiment is one of the highest priority scientific satellite instruments developed for NASA's Earth Observing System (EOS). The first CERES instrument was launched in December of 1997 aboard NASA's Tropical Rainfall Measurement Mission (TRMM), CERES instruments are now collecting observations on three separate satellite missions, including the EOS Terra and Aqua observatories and now also on the Suomi National Polar-orbiting Partnership (S-NPP) observatory



Radiation/CERES Assumptions



- The aircraft radiation measurements to be collected during ARISE will be our first opportunity to independently verify CERES radiative fluxes in this region.
- As such, overlap between aircraft radiation measurements and satellite observations is a high priority for radiation balance science objectives.
- From the data collected during ARISE, we hope to evaluate:

i) Observed CERES radiance & TOA fluxes.

- Main challenge is ensuring aircraft measurements adequately cover area observed by CERES (20-km resolution at nadir).
- Ideal aircraft altitude ~10 km.

ii) Computed CERES TOA and surface fluxes.

- These computations can be derived at MODIS pixel scale (~1 km) as well as CERES footprint scale (~20 km).
- Ideal aircraft altitude for TOA ~10 km. For surface: below clouds.
- Basic cloud properties are highly critical (amount, layering, height, thickness, phase), as are temperature/humidity profiles and surface properties. LVIS should be really helpful.

iii) Observed & computed gridded average CERES TOA & SFC fluxes.

- Sample larger scale (e.g., 100x100 km² regions) at TOA (10 km) & SFC.
- Target areas comprised of uniform sea-ice and open ocean conditions, as well as more heterogeneous surface conditions.
- Ideally, data collection in which solar elevation is 10° or more above the horizon.



3 types experiments for CERES validations



1. Ground track experiment

- C-130 follows the ground track of Terra, Aqua, NPP, and CALIPSO/CloudSat

2. Grid box experiment

- C-130 flies over a 100 km by 100 km grid box at 10 km or near the surface

3. Vertical profile experiment

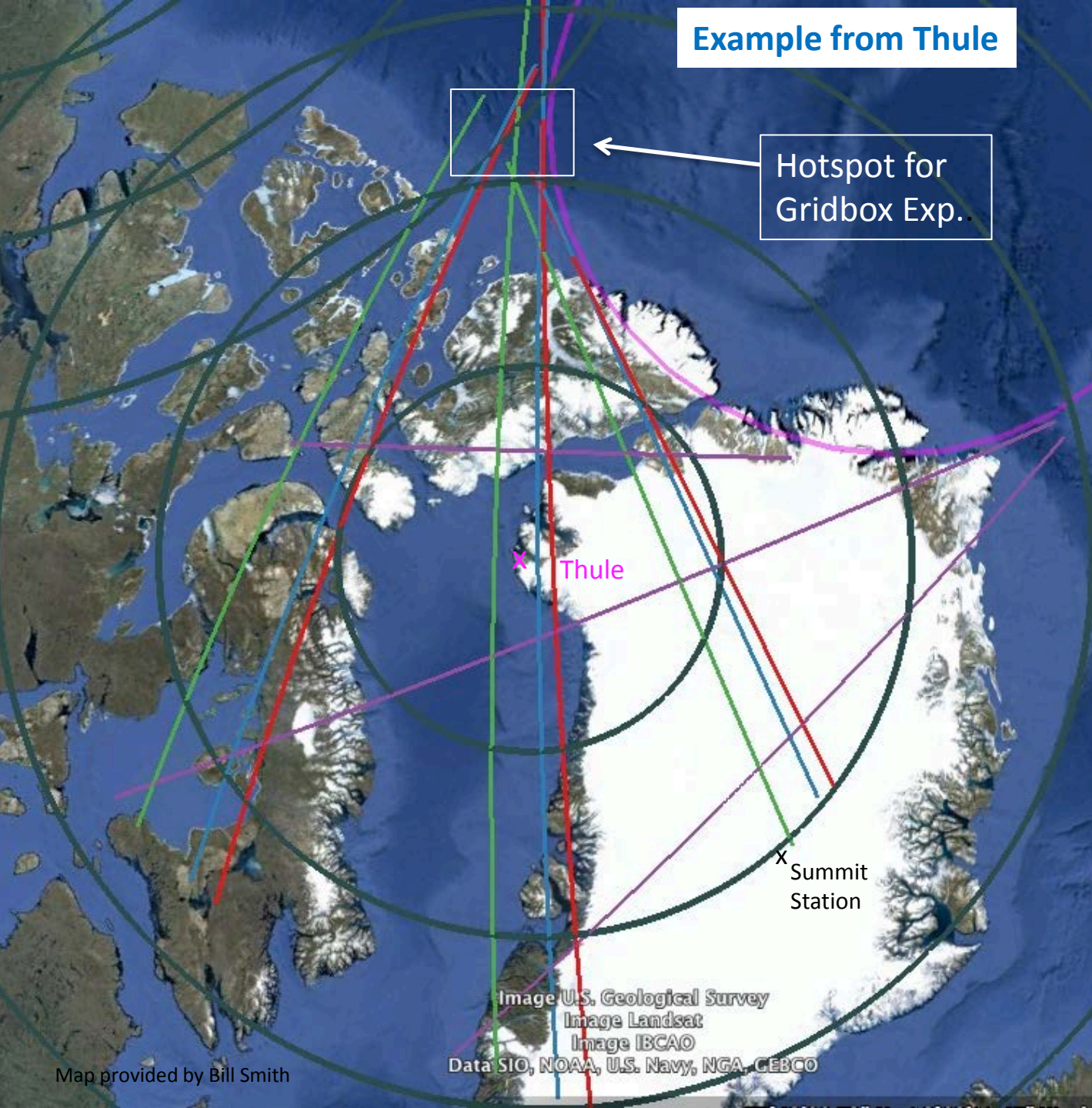
- C-130 flies over a ground site or over a ship at 4 to 5 different height to measure the spectral surface albedo and vertical profile of irradiances.

Example from Thule

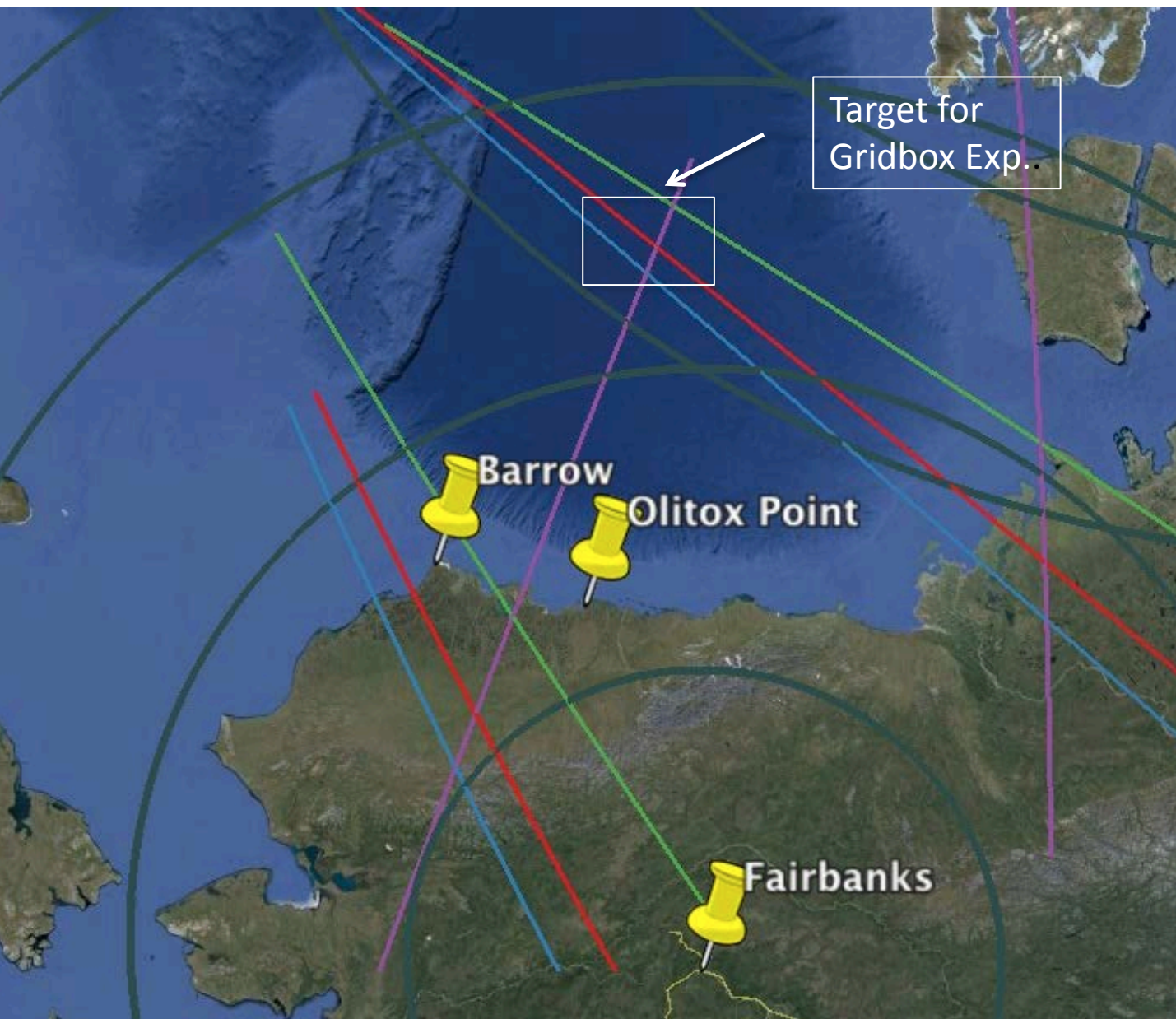
CERES
Satellite Overpasses
8-28-2014

— TERRA
— CALIPSO
— AQUA
— S-NPP

Range Circles
500 km (~1 hour)



Example from Fairbanks



CERES
Satellite Overpasses
9-9-2014

— TERRA
— CALIPSO
— AQUA
— S-NPP

Range Circles
500 km (~1 hour)



Thule flights

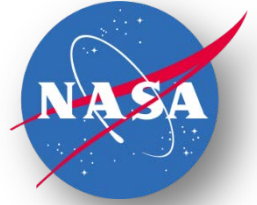
Date	Priority	Experiment	Target	Local time	Note
27-Aug	1	Grid box (set 1)	81N 121W	10:50-12:31	Sea ice, TOA
28-Aug	1	Grid box (set 1)	81N 121W	11:34-13:13	Sea ice, Surface
29-Aug					
1-Sep					
2-Sep	1	Vertical profile	Summit	10:16-11:32	Snow albedo

Fairbanks flights (Minimum requirements)

Date	Priority	Experiment	Target	Local time	Note
5-Sep	1	Sat. track/profile	Barrow	13:31	Terra is close to Barrow
6-Sep	1	Sat. track/profile	Olitox Pt	13:04	CALIPSO/Aqua near Olitox
7-Sep	1	Grid box (set 1)	75N 144 W	11:58-13:19	TOA
8-Sep	2	Sat. track			
9-Sep	1	Grid box (set 1)	75N 144W	11:20-13:07	Surface
10-Sep	1	Grid box (set 2)	75N 151W	12:39-13:50	TOA
11-Sep	2	Sat. track		12:54	Terra near Olitox point
12-Sep	1	Grid box (set 2)	75N 151W	12:05-13:38	Surface
13-Sep					
14-Sep	2	Sat. track		13:25	Terra is close to Barrow
15-Sep	1	Grid box (set 3)	75N 156W	12:49-14:08	TOA
16-Sep					
17-Sep	1	Grid box (set 3)	75N 156W	12:11-13:56	Surface
18-Sep	2	Sat. track		13:00	CALIPSO near Olitox Pt
TBD	1	TBD	TBD	TBD	MIRAI OVERFLIGHT

Fairbanks flights

Date	Priority	Experiment	Target	Local time	Note
19-Sep					
20-Sep					
21-Sep	3	Sat. track/profile		13:41	Terra is close to Barrow
22-Sep	3	Sat. track/profile		13:05	CALIPSO/Aqua near Olitox Pt
23-Sep	3	Grid box (Set 4)	75N 144W	11:58-13:29	TOA
24-Sep	3	Sat. track			
25-Sep	3	Grid box (Set 4)	75N 144W		Surface
26-Sep	3	Grid box (Set 5)	75N 151W		TOA
27-Sep	3	Ground track			
28-Sep	3	Grid box (Set 5)	75N 151W		Surface
29-Sep					
30-Sep	3	Sat. track			Terra is close top Barrow
1-Oct	3	Grid box	75N 157W		
TBD	1	TBD	TBD	TBD	MIRAI OVERFLIGHT

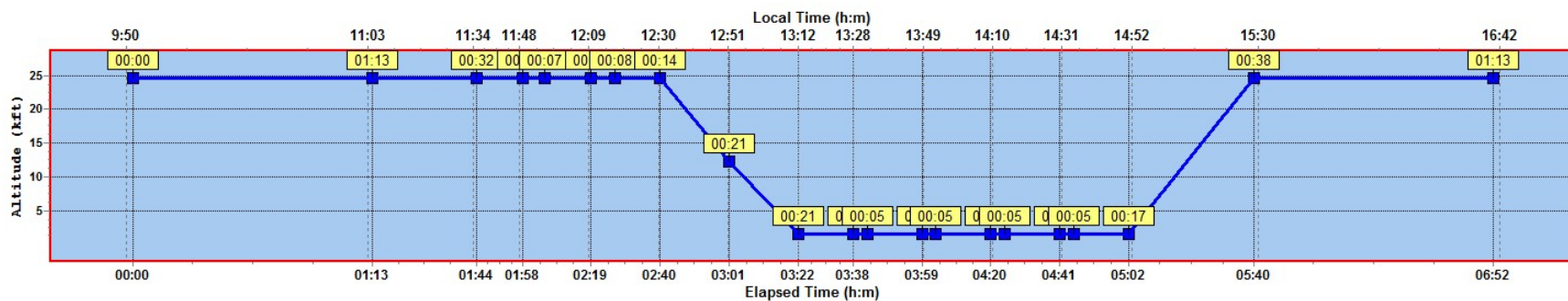
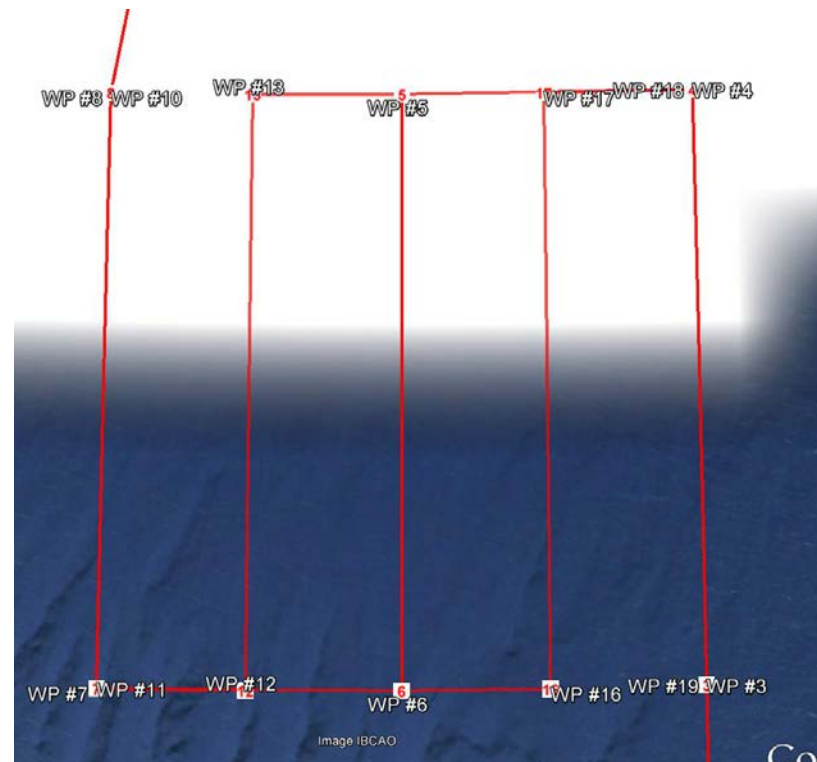
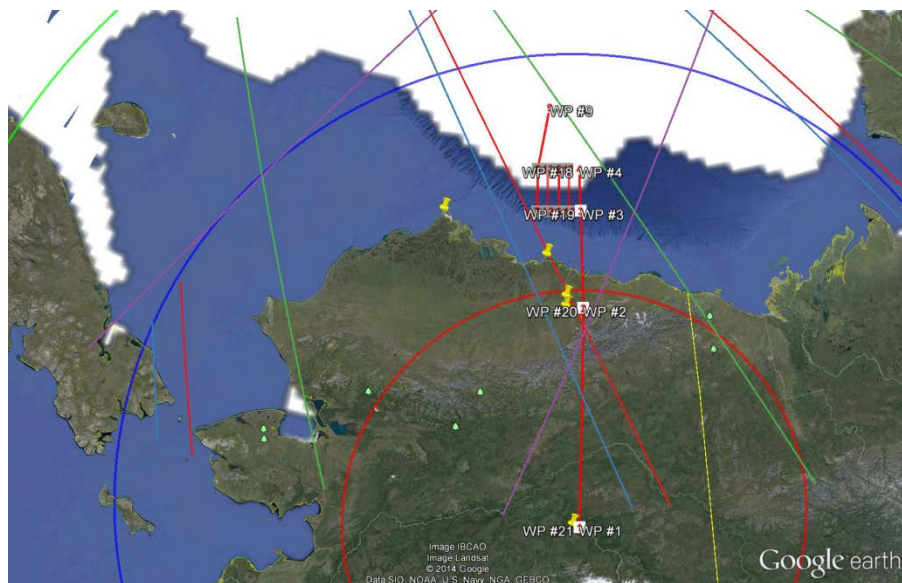


Proposed flight plans for general Radiation

BBR (Anthony), SSFR (Sebastian), 4STAR (Jens)

Fairbanks Lawnmower pattern –

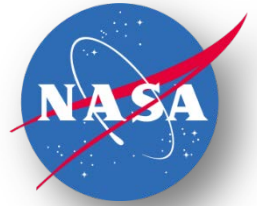
100x100km, centered on ice edge, timed to coincide with Terra&Aqua overpass during low level runs, currently timed at 6hrs 52min





Waypoints

Lat(+90)	Lon(+180)	Speed(m/	delayT(mi	Altitude(n	CumLegT(UTC(h:m)	LocalT(h:r	LegT(h:m)	Dist(km)	CumDist(k	Dist(nm)	CumDist(r	Speed(kt)	Altitude(k
64.814	-147.855	120	0	7500	00:00	17:50	9:50	0	0	0	0	0	233	24.606
69.5	-147.5	120	0	7500	01:13	19:03	11:03	01:13	520.96	520.96	281.29	281.29	233	24.606
71.55034	-147.5	120	0	7500	01:44	19:34	11:34	00:32	227.84	748.8	123.03	404.32	233	24.606
72.44966	-147.5	120	0	7500	01:58	19:48	11:48	00:14	99.94	848.74	53.96	458.28	233	24.606
72.44694	-148.956	120	0	7500	02:05	19:55	11:55	00:07	48.79	897.53	26.34	484.63	233	24.606
71.54762	-148.956	120	0	7500	02:19	20:09	12:09	00:14	99.94	997.46	53.96	538.59	233	24.606
71.54491	-150.412	120	0	7500	02:26	20:16	12:16	00:08	51.2	1048.67	27.65	566.24	233	24.606
72.44423	-150.412	120	0	7500	02:40	20:30	12:30	00:14	99.94	1148.6	53.96	620.2	233	24.606
73.77108	-149.573	120	0	3750	03:01	20:51	12:51	00:21	149.91	1298.51	80.94	701.14	233	12.303
72.44423	-150.412	100	0	500	03:22	21:12	13:12	00:21	149.91	1448.42	80.94	782.08	194	1.64
71.54491	-150.412	100	0	500	03:38	21:28	13:28	00:17	99.94	1548.35	53.96	836.04	194	1.64
71.54623	-149.701	100	0	500	03:42	21:32	13:32	00:05	24.98	1573.34	13.49	849.53	194	1.64
72.44555	-149.701	100	0	500	03:59	21:49	13:49	00:17	99.94	1673.27	53.96	903.5	194	1.64
72.44694	-148.956	100	0	500	04:03	21:53	13:53	00:05	24.98	1698.26	13.49	916.99	194	1.64
71.54762	-148.956	100	0	500	04:20	22:10	14:10	00:17	99.94	1798.2	53.96	970.95	194	1.64
71.54894	-148.246	100	0	500	04:24	22:14	14:14	00:05	24.98	1823.18	13.49	984.44	194	1.64
72.44827	-148.246	100	0	500	04:41	22:31	14:31	00:17	99.94	1923.12	53.96	1038.4	194	1.64
72.44966	-147.5	100	0	500	04:45	22:35	14:35	00:05	24.98	1948.1	13.49	1051.89	194	1.64
71.55034	-147.5	100	0	500	05:02	22:52	14:52	00:17	99.94	2048.04	53.96	1105.85	194	1.64
69.5	-147.5	120	0	7500	05:40	23:30	15:30	00:38	227.84	2275.88	123.03	1228.88	233	24.606
64.814	-147.855	120	0	7500	06:52	24:42	16:42	01:13	520.96	2796.84	281.29	1510.17	233	24.606



Proposed flight targets for Cloud Modeling

Lubin/Bromwich



Vertical Cloud Profile

Pinto, J. O., 1998: *J. Atmos. Sci.*, **55**, 2016

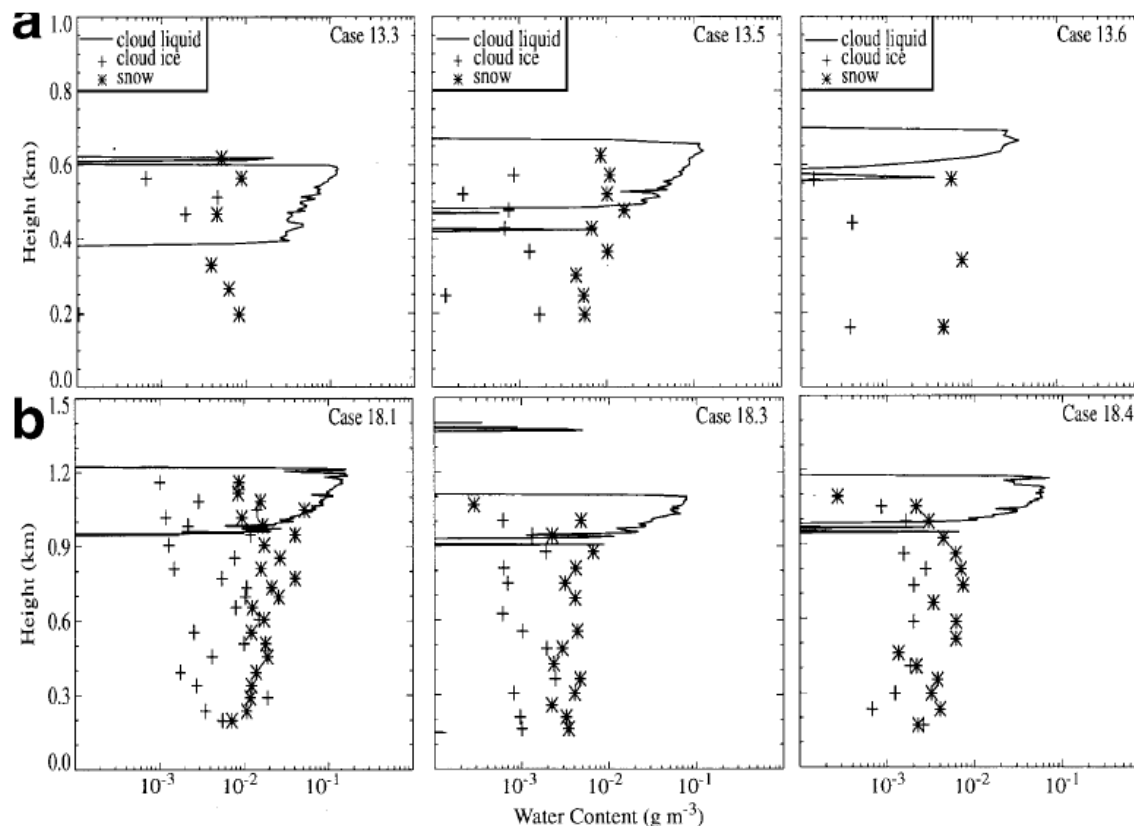


FIG. 12. Profiles of cloud liquid, cloud ice, and snow water content as determined for three aircraft profiles obtained during (a) case 13 and (b) case 18. Liquid water contents are given as 1-s King probe data. Ice and snow water contents are determined from 10-s averages of the 2D-C and 2D-P probe data.

- Cases 13 and 18 are Arctic autumnal mixed-phase clouds under cyclonic and anticyclonic conditions respectively.
- Fewer or no ice particles detected in top ~50 m of cloud, particularly as cloud ages.



Vertical Cloud Profiles

Pinto, J. O., et al., 2001: *J. Geophys. Res.*, **106**, 15077

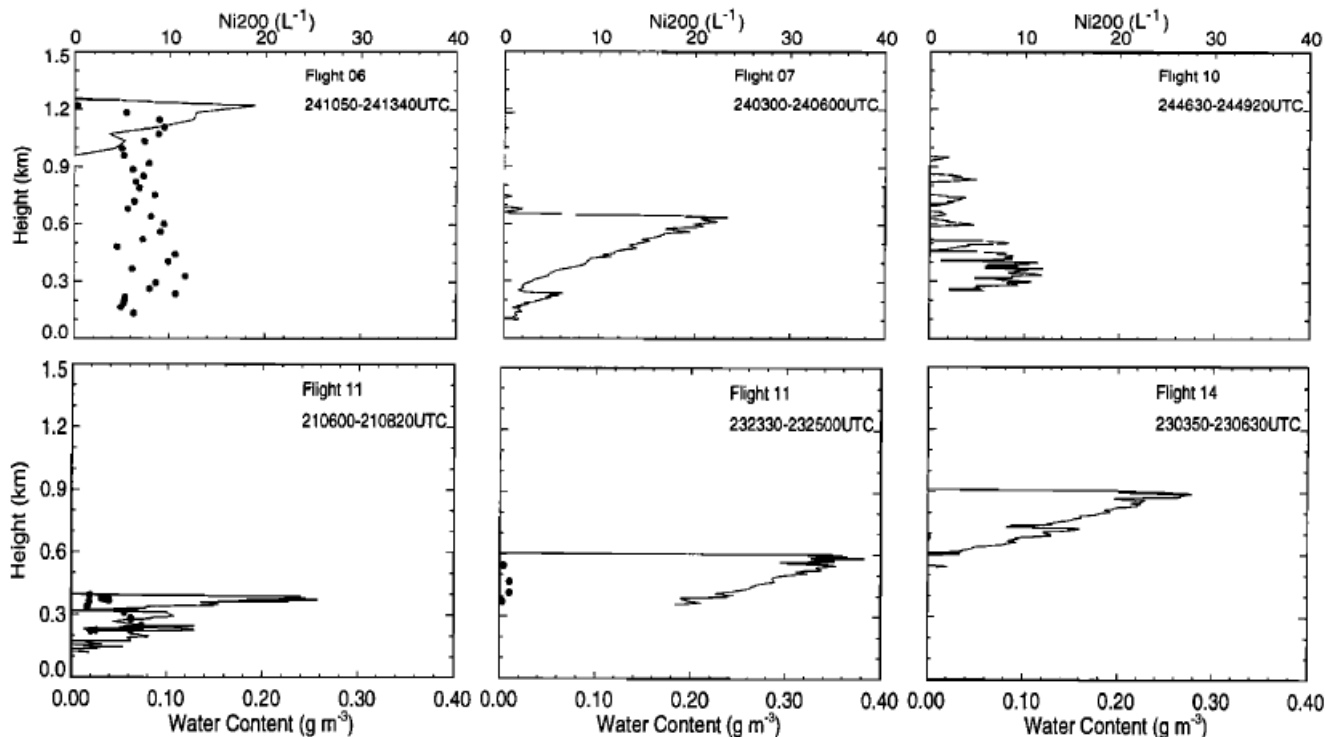


Figure 2. Profiles of liquid water content (LWC) (solid) and concentrations of ice crystal greater than 200 μm in diameter (circles), Ni200. LWC data are 1 s averages from the King probe; Ni200 data are 10 s averages from 2DC and 2DP probes. The LWC derived from the raw icing rate is used in place of missing King probe data in Flight 6.

- More autumnal mixed-phase clouds sampled over the Beaufort Sea.
- Note maximum in liquid water content at cloud top.



Vertical Cloud Profiles

Verlinde et al., 2007, *BAMS*, February, 205

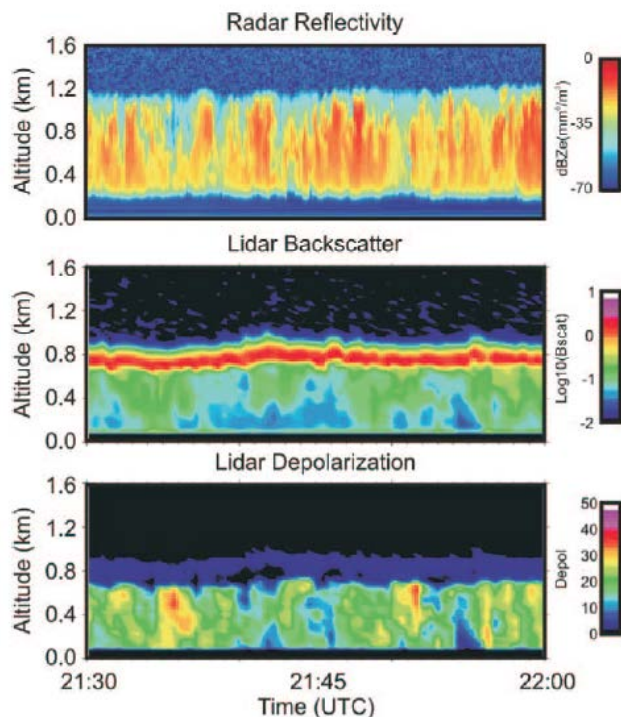
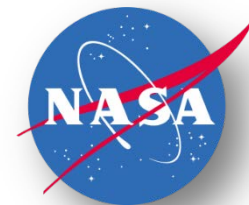


FIG. 6. PARSL (top) radar reflectivity, (middle) lidar backscatter, and (bottom) depolarization for the UND Citation overflight on 10 Oct 2004.

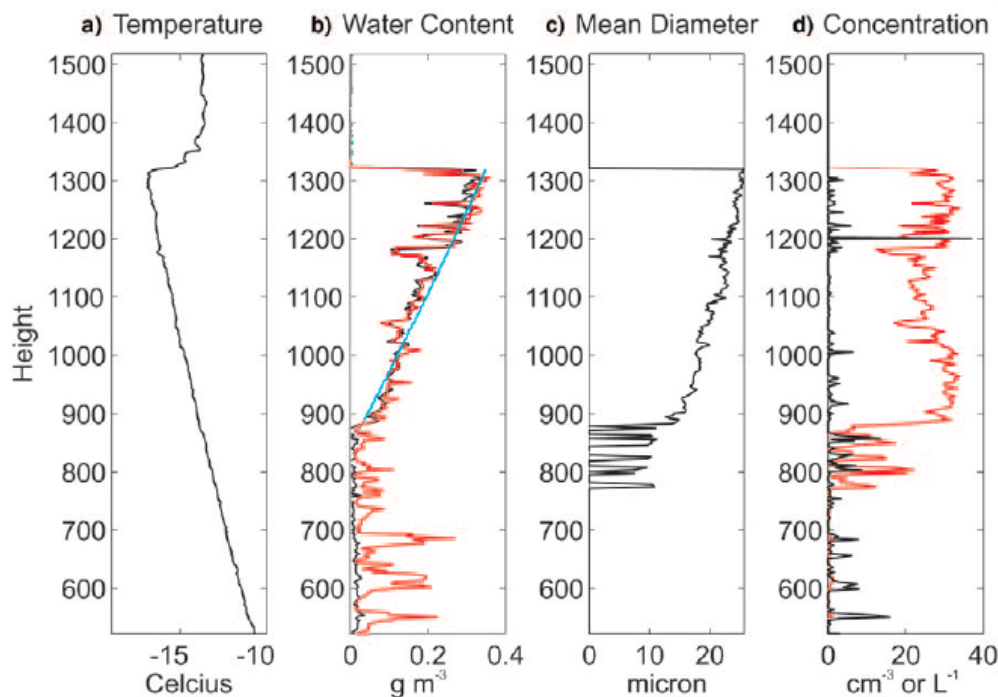


FIG. 7. UND Citation in situ measurements from a single spiral over Oliktok point at 2145 UTC 10 Oct 2004, corresponding to the PARSL observations in Fig. 6. (a) Temperature and (b) liquid (measured and calculated adiabatic) and total water content from the King probe (black), calculated (blue), and CVI (red); c) mean diameter from the FSSP; and (d) number concentration from the FSSP (red) and 2DC probes.

➤ Another example of a mostly liquid water cloud, with most LWC at top, and ice below.



Vertical Cloud Profiles

Verlinde et al., 2007, *BAMS*, February, 205

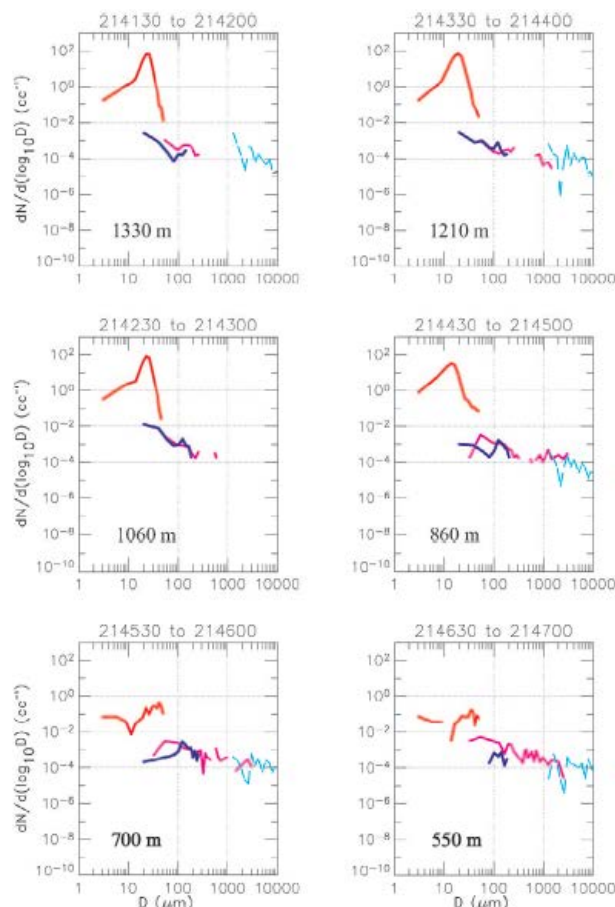


Fig. 8. Example of 30-s-averaged size distributions measured between 2140 and 2147 UTC 10 Oct 2004 for the same profile as that shown in Fig. 7. The distributions are derived from FSSP, IDC and 2DC, and HVPS probes (see McFarquhar et al. 2005).

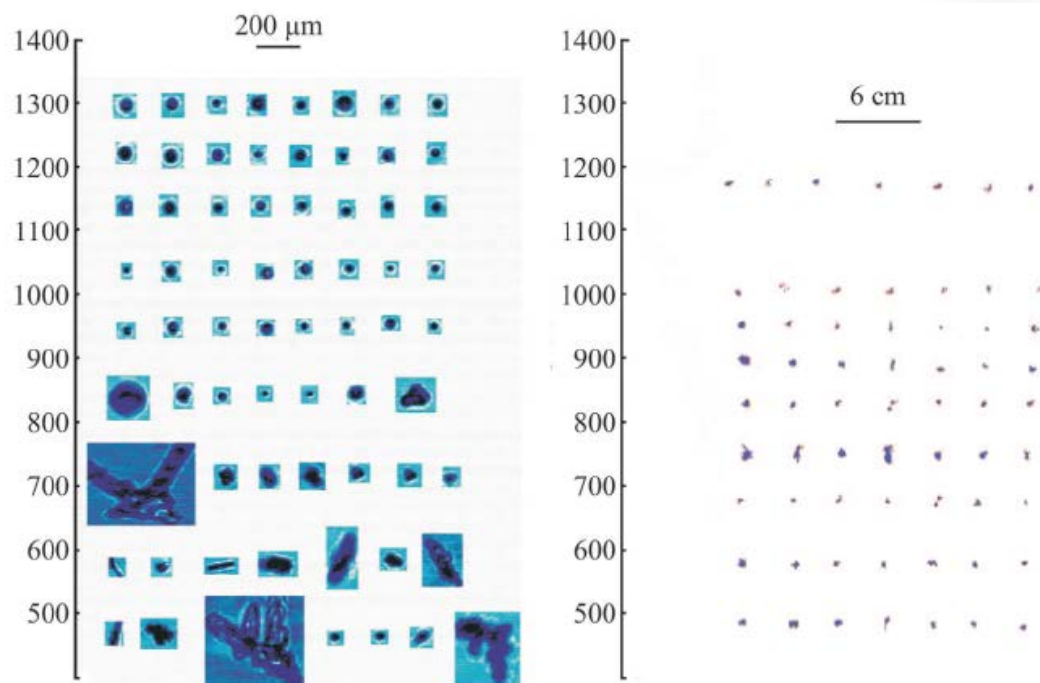


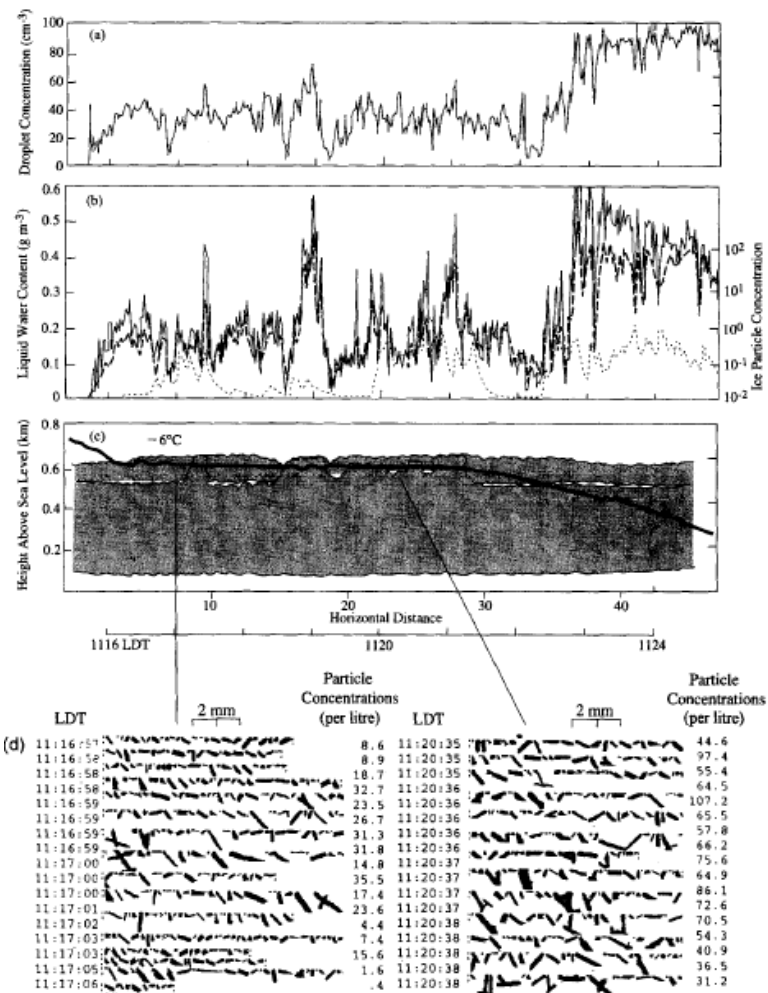
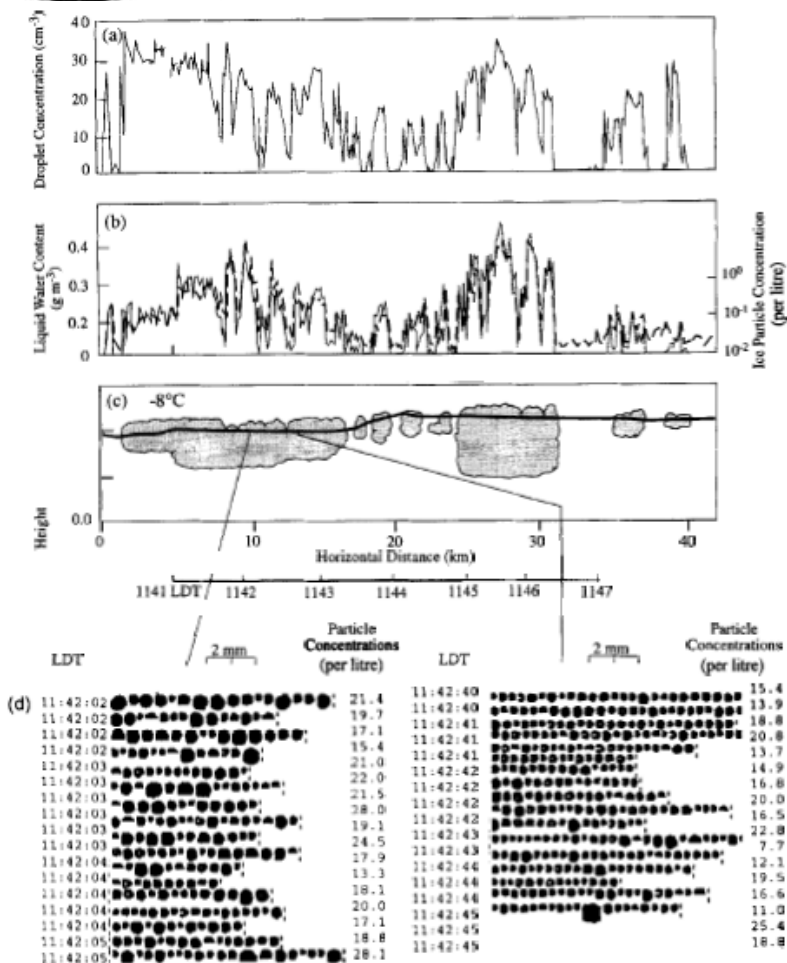
Fig. 9. Examples of selected CPI and HVPS images measured between 2140 and 2147 UTC 10 Oct 2004 for the same profile as that shown in Figs. 7 and 8. The smaller spherical images near cloud top (CPI) are small drizzle or supercooled drops. Larger ice crystal images show dominance of irregular and rimed crystal shapes. Even though the largest crystals measured by HVPS are more frequent near and below cloud base, they can occur throughout depth of cloud (see McFarquhar et al. 2005).

➤ More microphysical measurements from this M-PACE example.



Cloud Top Transects

Hobbs, P. V., and A. L. Rangno, 1998: *Q. J. R. Meteorol. Soc.*, **124**, 2035



- Mixed-phase clouds sampled near cloud top on June 3 (left) and June 4 (right) of 1995 over Beaufort Sea under mainly cyclonic conditions but with daily variability.



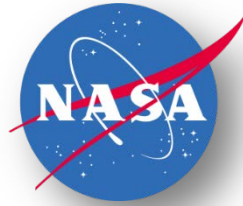
Note: Time hacks are rough estimates; will need to be validated



“Satellite Track” Sampling

Upon arriving at target cloud deck:

- 1) Starting Point: Descend from cloud top to cloud base (~3 min.) then ascend to cloud top (~3 min.) to obtain vertical profile of liquid water and state variables. [Spiral descent/ascent or straight flight path? – Ask instrument mentors for preferences.]
- 2) Outbound Leg Along Cloud Top: Fly ~40 km horizontal leg skimming cloud top (~7 min.) to ascertain cloud top altitude and measure cloud-free downwelling radiation and whole cloud/surface upwelling radiation.
- 3) Vertical Profile: Descend with 180-degree turn from cloud top to cloud base (~3 min.) then ascend with another 180-degree turn to cloud top (~3 min.) to obtain another full vertical profile of liquid water and state variables, and return to end of cloud-top leg of (2).
- 4) Return Leg in Cloud: From cloud top, make another 180-degree turn, descend to approximately 100 m below cloud top, fly ~40 km horizontal leg (~7 min.) backtracking on approximately the same path as the cloud-top leg of (2), to sample:
 - cloud attenuation of downwelling spectral and broadband radiation in liquid-dominated regime, and
 - mixed-phase influence on upwelling radiation.

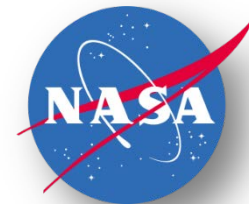


“Satellite Track” Sampling (continued)

5. Vertical Profile: Return to cloud top (~1 min.), make a descent to cloud base with 180-degree turn, to obtain another vertical profile (~3 min.), to end up at/near starting point (1).
6. Second Outbound Leg at Cloud Base: Fly ~40 km leg (~7 min.) at cloud base, retracing approximately the outbound cloud-top leg of (2), to sample downwelling radiation influenced by mixed-phase, and upwelling radiation from surface.
7. Vertical Profile: Return to cloud top for a final vertical profile (~3 min.). Total time for this evolution is approximately 40 minutes.
8. After Sun has left optimal elevation range, make several more vertical profiles to more completely sample liquid water and state variables. This can also be done before cloud-radiation transects, if aircraft arrives at target cloud deck early.

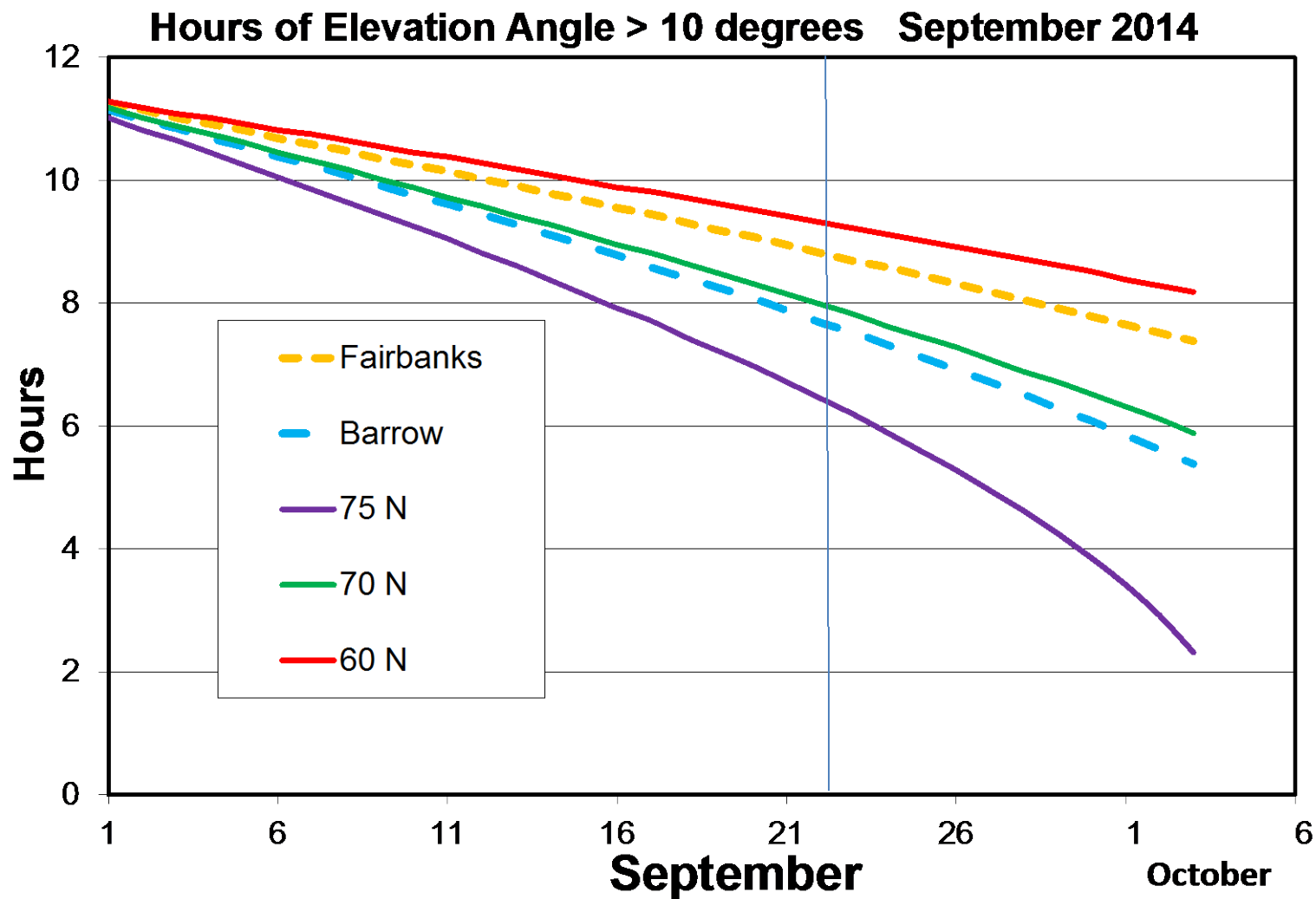
Variations:

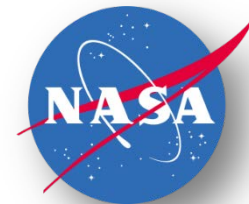
- If cloud is thicker than 200 m, add a second in-cloud transect plus full profile from cloud top, for an additional 14 minutes.
- If multilayer clouds, fly 40 km stacked transects between the layers, and above top of highest layer and below base of lowest layer if possible.



Hours of Useful Sun Elevation

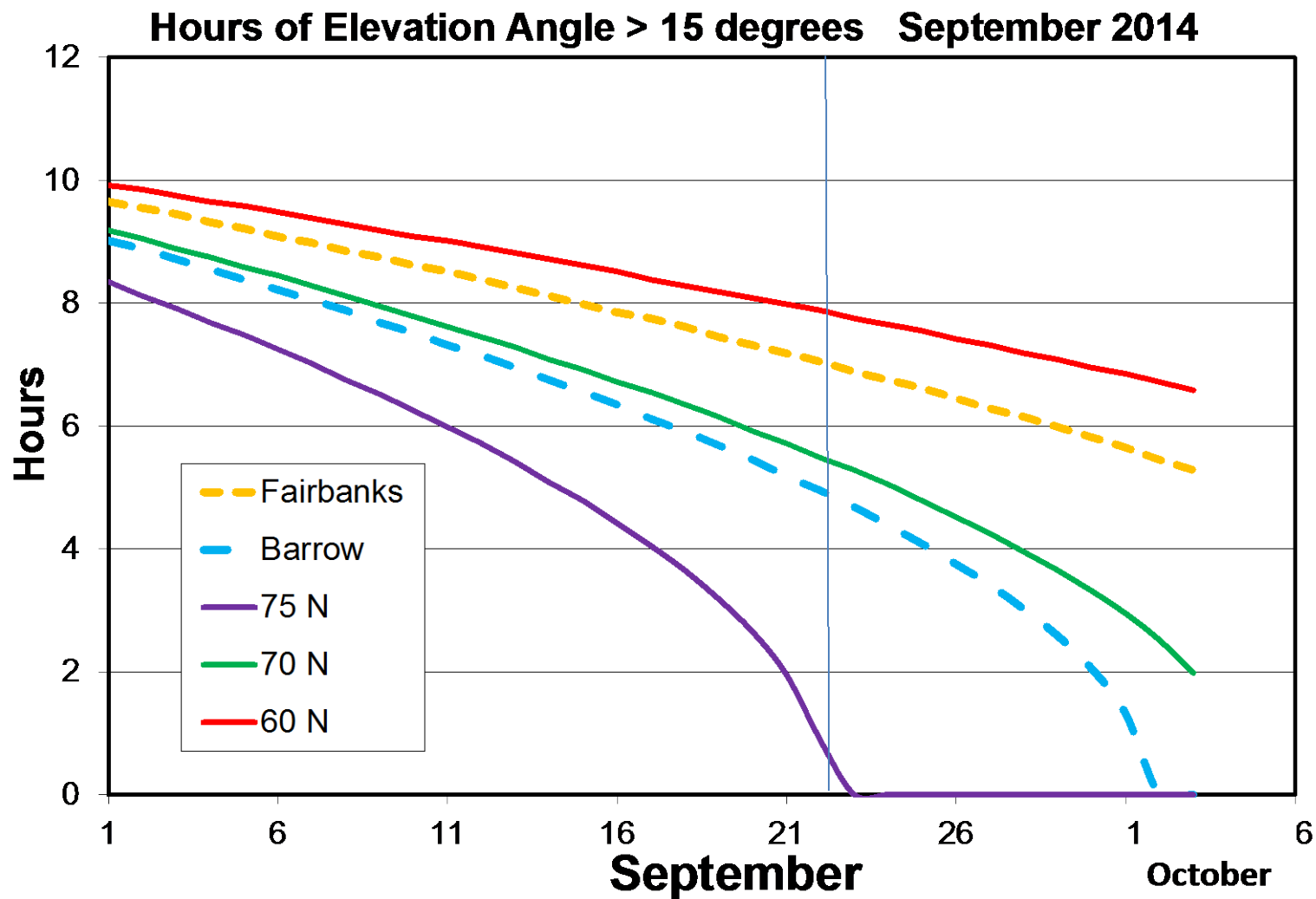
Absolute Minimum

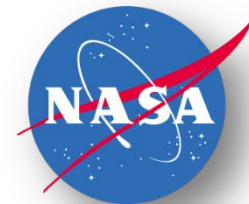




Hours of Useful Sun Elevation

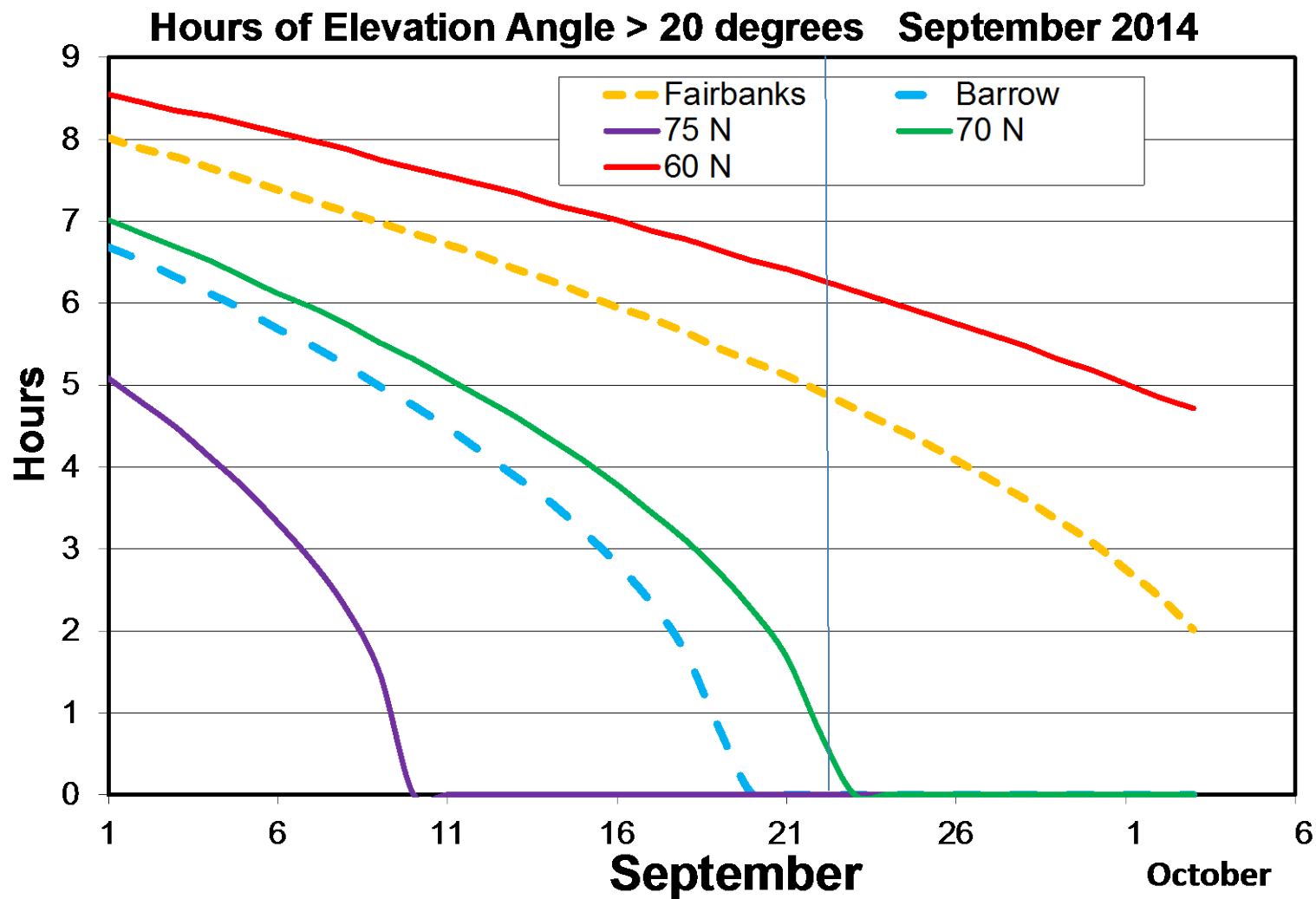
Useful Shortwave Retrieval Range





Hours of Useful Sun Elevation

Optimal Shortwave Retrieval Range





Cryospheric/IceBridge Sea Ice & Land Ice Flight Line Planning

Richter-Menge/Koenig/Hofter/Beckley

Assumptions

1. All instruments will record data at all times, regardless of primary flight objective
2. Even though this presentation shows separate lines for radiation vs. ice targets, objectives can and will overlap; where feasible, we will try to obtain multiple objectives in any given flight

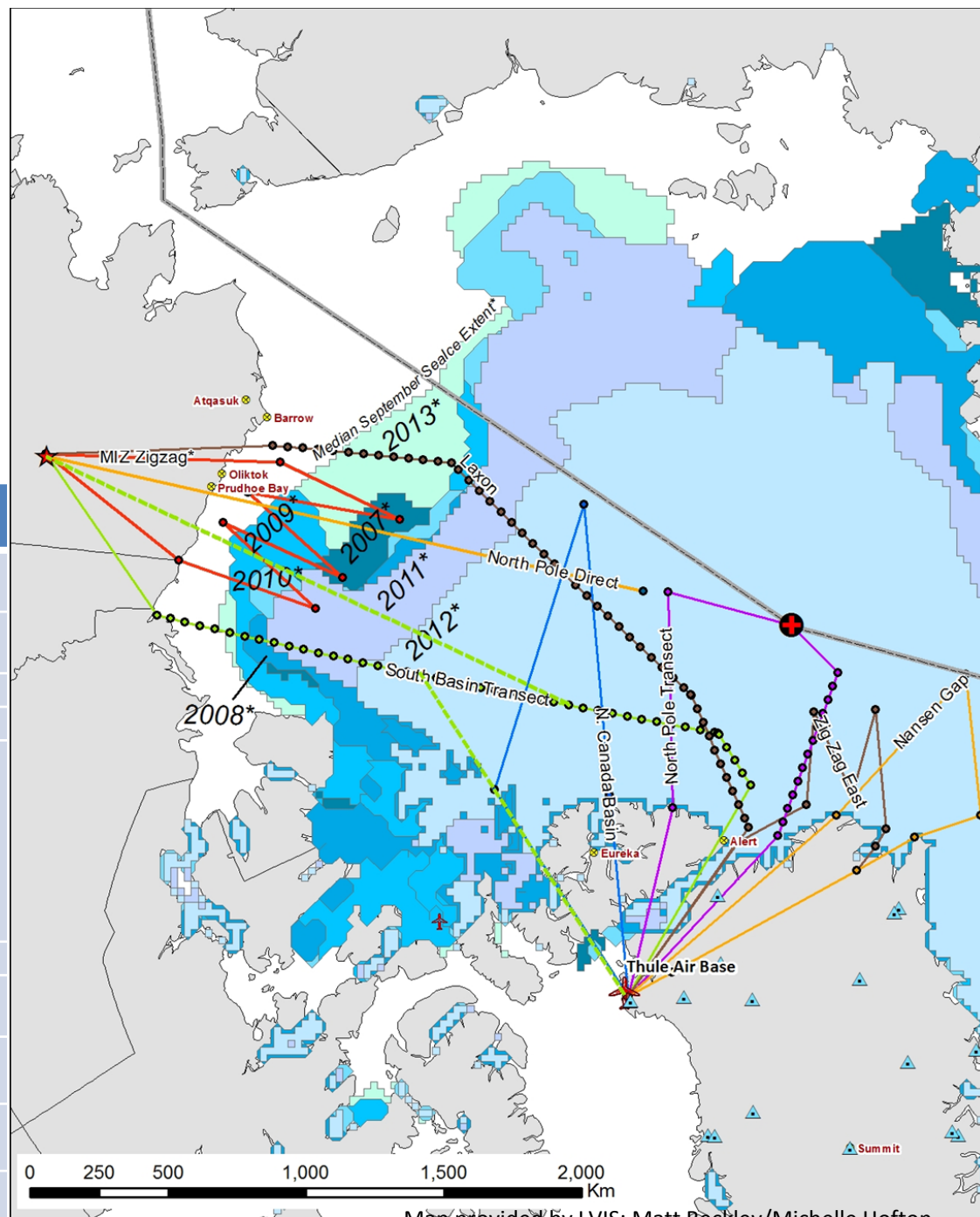
IceBridge Sea Ice Flight Lines

- + To be flown as the transit if conditions are poor along the South Basin Transect route.
- * Preferred flight option will be chosen when it becomes clearer where the ice edge is.
- ** Among the 4 options, ice edge conditions permitting, this flight option is the most desirable, noting that it coincides with interests of cloud team.

Note: Potential land ice opportunities also on these flights.

- ^ Location depends on position of ice edge.
- # If not flown out of Thule. No need to repeat if flown via Thule/Thule or Thule/Fairbanks.

Base	Flight	Duration (300kts)	Priority
Thule/Fairbanks	S Basin Transect	7hrs	High
Thule/Fairbanks	Laxon Line+		Alternate
Thule/Thule	S Basin Transect	8hrs	Medium
Thule/Thule	Canada Basin North**		
Thule/Thule	Nansen Gap*	6.6hrs	
Thule/Thule	Zigzag East*	6.3hrs	Highest
Thule/Thule	North Pole Transect*	6.5hrs	
Fairbanks/Fairbanks	MIZ Zigzag ^	8hrs	Highest
Fairbanks/Fairbanks	MIZ Zigzag Repeat		High
Fairbanks/Fairbanks	North Pole Direct	8 hrs	High
Fairbanks/Fairbanks	S Basin Transect	8 hrs	Medium#



Map provided by LVIS: Matt Beckley/Michelle Hofton



Notes:

Canada Basin North/Nansen Gap/ZigZag East/North Pole Transect

Conducting one of these missions is the highest priority during the Thule-based operations. Among the candidate missions, Canada Basin North is ranked highest, noting that it coincides with one of the satellite 'hot spots' identified by the cloud team.

In all cases, the opportunity should be sought underfly CS-2, following the approach used in Spring 2014 when the eastern-most leg of the North Pole Transect was modified to coincide with a CS-2 orbit.

Transit to Fairbanks

Primary option is S Basin Transect, if not already flown. If it has been flown before departing Thule OR if conditions are poor (i.e. lots of clouds) at the time of the transit, the Laxon Line should be flown instead.

MIZ Zigzag

Example only. Idea is to fly from open to ice/water to pack. And Zigzag over that. And repeat at intervals to assess evolution of ice edge.

MIZ Zigzag Repeat

Suggested repeat interval: ~a week. Repeat as many times as possible. Try to use same flight altitude as initial flight for the repeats.

North Pole Direct

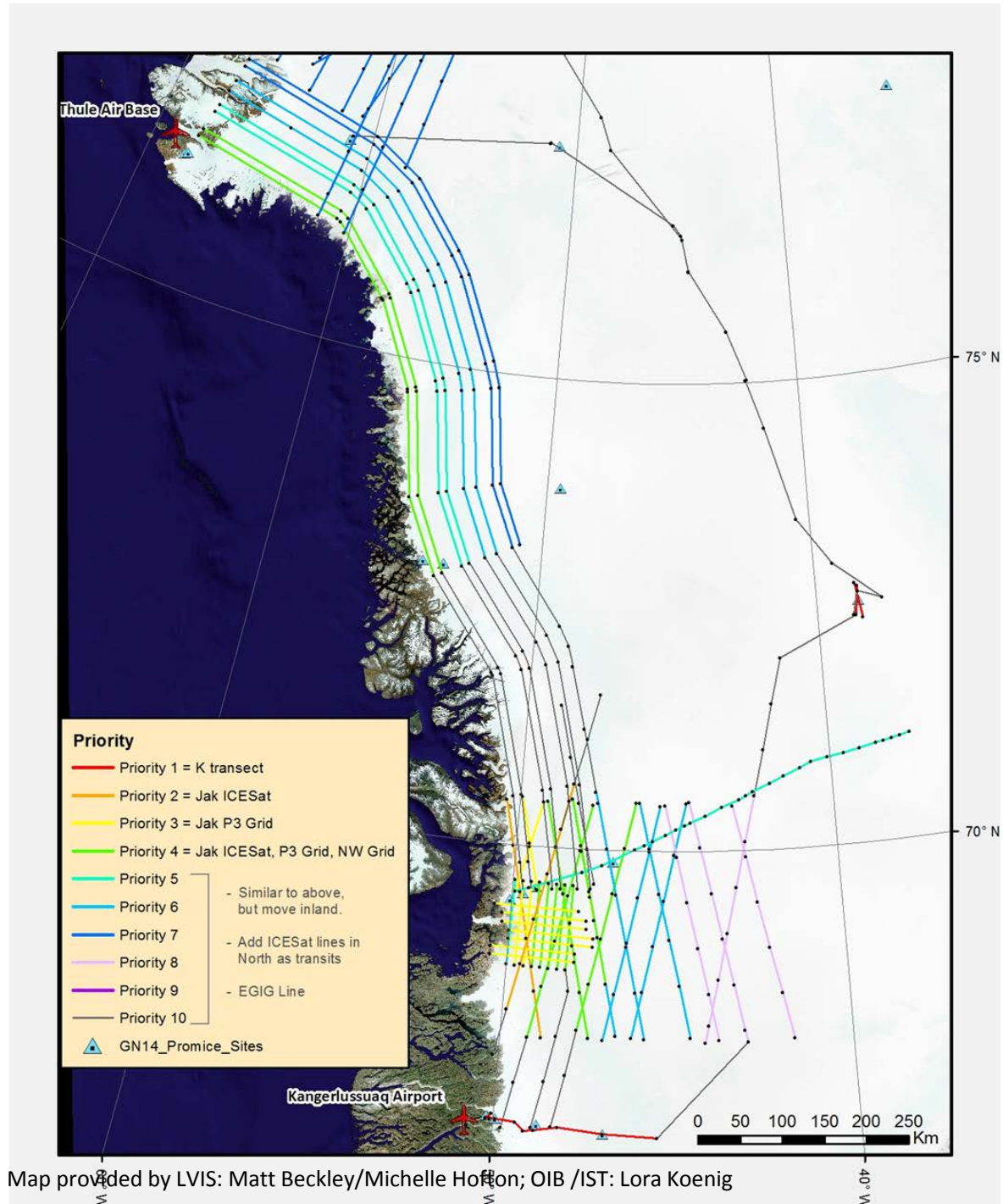
A driver on this flight is MABEL, which is scheduled to make a similar flight earlier in the summer season. We want to be able to compare ice conditions in the same region. If MABEL becomes less of a motivation, let's adjust the line to get over as much ice as possible. Don't need to repeat the exact leg on return, travel back at a slight offset instead.

Preferred flight configuration: 28,000'/300 knots, or, as high/fast as possible

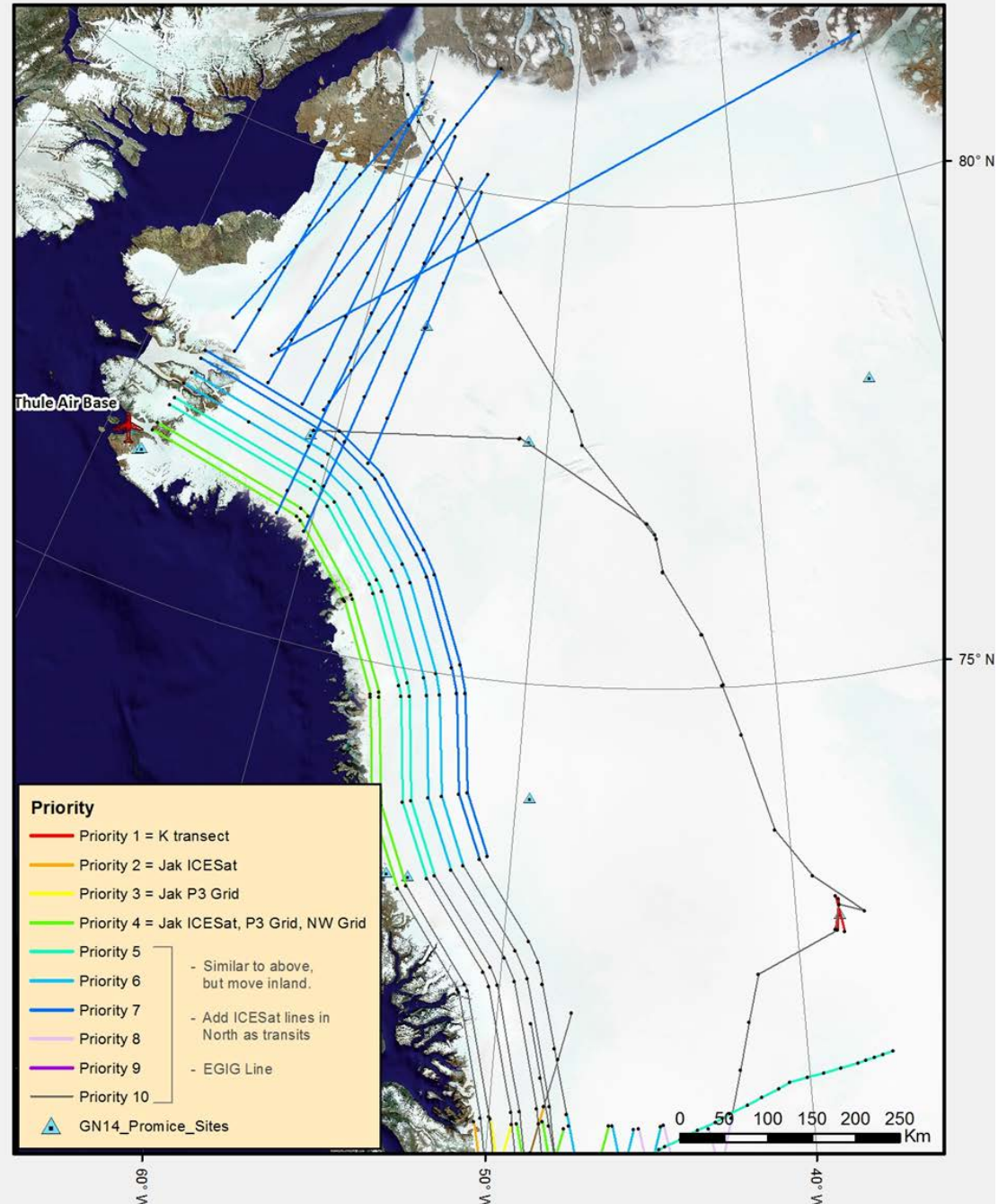
IceBridge Land Ice Flight Lines

Priority flights or flight sections (in order):

1. K-transect
2. Jakoshavn ICESat Grid
3. Jakoshavn P-3 grid lines
4. EGIG line
5. Any west coast grid lines (~5-10 km from ice edge).



IceBridge Land Ice Flight Lines (cont)





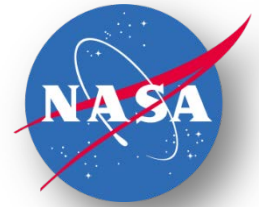
General Land Ice Priorities

1. Attempt to transit on Southern Coastal Grid.
2. In the South, the K-transect is top priority.
3. The priority if in the Jakoshavn area is 1) the two coastal most ICESat grid lines and 2) the Jakoshavn grid starting from the coast perpendicular straight center lines and moving outward.
4. If near the Summit area, make sure to do the small segment of ICESat track 412 and the ICESat-2 line provided by John Sonntag.
5. The EGIG line is also important as it follows many field stations that have Radiative Balance measurements. However, the EGIG line is of secondary importance to the K-transect line.
6. From the P-3 2014 kmz we received, lines marked "annual" are the highest priority. Attempt to fly along during any ice sheet transits.
7. Ideally, we should fly 5-10 km from the ice edge. We want to maximize measurements over the dynamic regions of the ice sheet. In general, this means flying coast parallel lines, 1 to 2 lines in from the ice edge.
8. In general fly flight lines near the coast, stay out of middle or center of the ice sheet.

(From ppt file from L Koenig, emailed 6/30/14)



Instrument Constraints & Requirements (input needed)



Instrument Planning Guidelines - teams check and edit

LVIS

1. If no other constraints, LVIS prefers 28,000 feet.
2. LVIS will need a ramp pass prior to every landing
3. LVIS prefers flying under clouds, when possible (if cloud deck is solid)
4. C-130 to not exceed 15 deg bank angle I roll or pitch for LVIS (preserve traj and precision GPS)
5. require calibration maneuvers twice a flight over open/flat-ish water: pilots rolls the plane by $\pm 10^\circ$ several times. Returns to flat and level. Then pitches up/down several times by as much as he's comfortable (typically $\pm 5^\circ$).

BBR/SSFR

1. full altitude range
2. BBR will need a cal pass over Barrow
3. Constant level for at least xx (10?) minutes to achieve thermal equilibrium (may primarily impact BBR since the instrument domes and bodies are exposed to the airstream. BBR team may have ways to mitigate this with instrument dome thermistors)

4-STAR

1. prefers to be low
2. solar elevation angle requirements are TBD after installation; we can track the sun all the way to the horizon, the question is fuselage interference (direct and through glint)
3. langley plots mnvrs: 3x3.5 hrs, during transits, C-130 high so 4-STAR can track the sun during sunrise or sunset for cal
4. prefers right bank turns and spiral descents/ascents
5. No requirements for ascent/descent rates

General

1. Require level flight with pitch/roll angles within \pm xx (5?) degrees relative to the plane of the mounting plate(s)
2. Dry, condensation free, precipitation free domes and windows